FINGERPRINT RECOGNITION SYSTEM TO VERIFY THE IDENTITY OF A PERSON USING AN ONLINE DATABASE

A thesis report submitted in partial fulfillment of the requirements for the degree of

BACHELOR OF TECHNOLOGY

In

ELECTRONICS AND INSTRUMENTATION ENGINEERING

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Declaration:

We hereby declare that all the works, designs and ideas implemented here are our independent effort and only guidance of our faculty and seniors except or otherwise clearly specified throughout the report thesis and hence I also made it certify that our project on ‘online minutiae matching fingerprint recognition technique ’ for verification of identity of person using online database, according to our way of study, has never been submitted for academic or any other purpose like getting credits in employment or any other things.

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Date: 12th April, 2012

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This is to certify that the thesis entitled, "fingerprint recognition system to verify the identity of a person using an online database" submitted by 'HIMANSHU SEKHAR GOUDA' and 'MANISH KUMAR' in partial fulfillments for the requirements for the award of Bachelor of Technology Degree in ELECTRONICS & INSTRUMENTATION ENGINEERING at National Institute of Technology, Rourkela (Deemed University) is a work carried out by them under my supervision and guidance.

Date: 14th May, 12
Place: Rourkela

Prof. Sukadev Meher
Department of Electronics and Communication Engineering

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And we extend our sincere thanks to all of our friends, classmates and some special friends whom I would like to mention like Debesh Kuanr and Gigyanshu Pradhan for helping us with the algorithm and moral support in this project.

Date – 12/5/2011

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CONTENTS

Page No.

LIST OF FIGURES

ABSTRACT:

Our B.Tech project emphasize on the current techniques for the fingerprint recognition. Human fingerprint exhibit some certain details marked on it. We categorized it as minutiae, which can be used as a unique identity of a person if we recognize it in a well manner. The main aim of this project is to design a complete system and an indigenous design model for fingerprint verification from an online database using minutiae matching technique. So, in order to have a good quality minutiae extraction the fingerprint image is first pre-processed by image enhancement which includes histogram equalization, Fast Fourier Transform and binerization and then segmentation is done to get the effective area of the fingerprint followed by minutiae extraction which includes ridge thinning and minutiae marking and then we have a post-processing operation which includes removal of H-breaks, isolated points and false minutiae. Now, we go for a final treatment which is ‘minutiae matching’, in minutiae matching we match the post-processed fingerprint image with the online database.

For all these operations, we develop an alignment based matching algorithm which is for minutiae matching. This algorithm has a specialty that it itself finds the correspondences between input minutiae and the stored template minutiae pattern and there is no resorting to exhaustive search. We can then evaluate the performance of the system on a database by taking fingerprints of different people.

CHAPTER 1

Introduction

1.1 What is a finger-print?

A finger-print is a pattern of feature of a finger as shown in the figure 1.1.1 given below. As per with the strong evidences, it is believed that each fingerprint in this world is unique and so each person of this world has a unique fingerprint with a permanent unique characteristics over it. That's why fingerprints are being used for various forensic investigation and identication from a long period of time. Nowadays, we also use fingerprints for many purposes like, to note down daily attendance and to get an automatic database retrieval system.

Figure1.1.1 A fingerprint image using an Optical Sensor

A fingerprint has many ridges and furrows. We can see good similarities between these ridges and furrows for a taken small local window, like average width and parallelism.

However, on the basis of intensive research on fingerprint recognition, we come to the conclusion that fingerprint are not recognized using their ridges and furrows, but minutiae plays a vital role over here, which are characterized by some abnormal points on the ridges as shown in below figure (1.2.2). and in figure (1.2.3 and 1.2.4) we can see a variety of minutiae. Although we can have a variety of minutiae types as per with literature, but two types of minutiae are mainly used and most significant and we'll also extend these in our project. In which, one is called 'termination' which can be characterized as the immediate ending of a ridge and the other one is called 'bifurcation' which can be characterized as the point on the ridges where two branches are bifurcated as shown in figure (1.1.2)

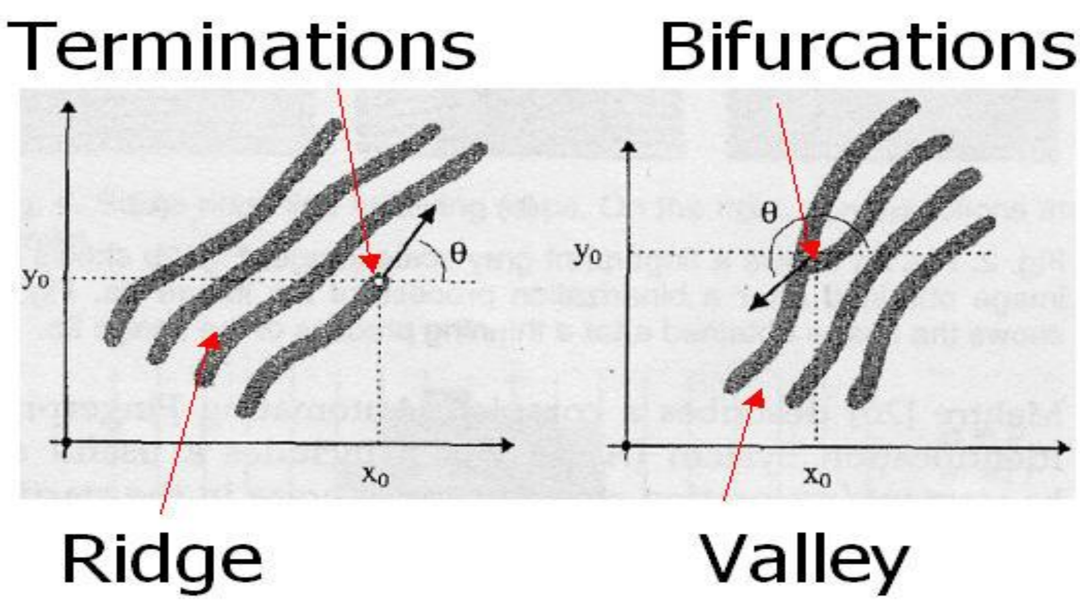


Fig 1.1.2 : Minutiae (ridge termination and bifurcation)

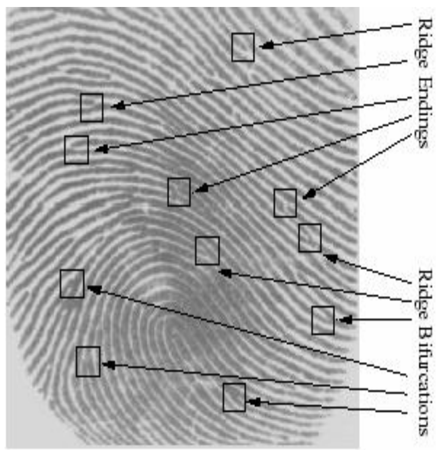


Fig 1.2.3: Minutiae points on a fingerprint

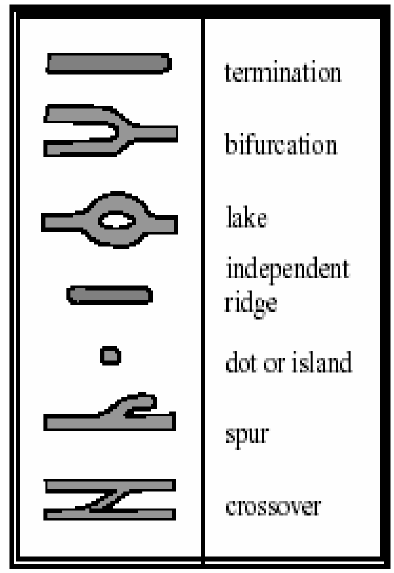


Fig 1.2.4 Different types of minutiae

1.2 Motivation and Challenges:

What we see in every organization, whether it is a business organization, educational colleges or institution, it has to classify each individual on the entrance gate either for attendance or for their department identification for an effective functioning in a well-mannered way. So, designing and automatic system which can verify their identity just by recognizing their fingerprints will reduce the man-work and also introduce a time saving mechanism with better operating capabilities we can even made it a lot faster and get some personal information of the person also using online databases. It's our responsibility to make an indigenous design which can operate with such constraints with an improved fingerprint recognition system. So, we have decreased the finger-print matching time just by using an inherent online database, it means we need not have a very large database just the required member's data will be there.

1.3 Using Biometrics:

Some of the instruments used for unique identification of humans includes biometrics identification systems known mainly for identification and verification. Here, we will use biometrics as for access management and access control of identity. So, use of biometrics in fingerprint recognition is secure and easy for image acquisition step in fingerprint recognition as well. We can see a lot varieties of biometric systems like face detection, fingerprint recognition, iris recognition, voice recognition, palm recognition etc. in our project we will only go for fingerprint recognition using a biometric device to capture fingerprint image.

1.4 WHY WE USE FINGERPRINTS:

Fingerprints are considered as a unique identification of a person and due to easy access it’s the best and one of the fastest method used in biometric identification systems. They are unique, so secure and reliable to use and doesn’t change for one in a lifetime. And beside these things fingerprint recognition specially using minutiae matching technique is cheap, reliable and accurate up to a satisfactory limits.

Hence, fingerprint recognition is being widely used in both civilian and forensic applications. If, we will compare with other biometric devices then fingerprint recognition devices will hold the maximum market share and are most proven ones also. And we can also say that it’s not only faster than other biometric devices but it’s energy efficient also, as it consumes very less energy.

1.5 WHAT DO YOU MEAN BY FINGERPRINT RECOGNITION? :

Here we are going with 'minutiae matching technique' for fingerprint recognition which can be divided into two sub-domains: one can be classified as fingerprint verification and other one can be classified as fingerprint identification (fig 1.5.1). And as we are using a different technique from manual approach for fingerprint recognition, we can say this technique system as 'Automatic Fingerprint Recognition System' (AFRS) , which is coded using Matlab(matrix-laboratory)

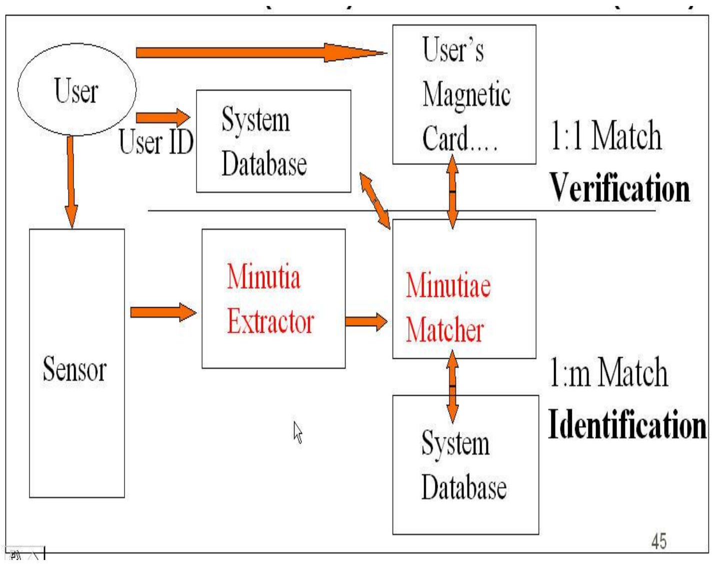


FIG 1.5.1 Verification and Identification

Fingerprint verification is the final step of fingerprint recognition used to verify the identity or say authenticity of one person by his fingerprint. In this mechanism what we are going to do is to have a user who will give his fingerprint along with his unique identification number. Now, the system will search his fingerprint using the unique identification number an d if the fingerprint matches then result will be positive otherwise negative. Basically, it is based on design principle of AFAS (Automatic Fingerprint Authentication System)

Fingerprint identification deals with the specifying the identity of a person by his fingerprint without knowledge of the identity of the person. In this method , generally a large database is stored and the fingerprint taken by the user is matched with the whole database fingerprints. Its' uses can be seen in criminal investigation cases and it is based in the design principle of AFIS (Automatic Fingerprint Authentication System).

But, in the end we can say that all fingerprint problems either verification or identification all start with the same technique of fingerprint recognition and are based on a well-defined representation of a fingerprint. As for the evidences as far as the fingerprints are unique , either we use 1 to 1 verification or we use 1 to m identification case, both will start with the same procedure with some straightforward and easy steps

1.6 APPROACHES FOR FINGERPRINT RECOGNITION

There are two types of representation, we can classify for fingerprints which make the two approaches for fingerprint recognition.

The first approach is 'Minutiae based', which represents the fingerprint by its local feature mainly stated are the two minutiae features as termination and bifurcation. This approach has been studied intensively and is mainly followed in current fingerprint recognition instruments. My project is also related to this technique with possible corrective measures based on experiments.

The second approach uses image-based method; it basically tries to match the whole fingerprint image using the global features. It is the latest and advanced techniques for fingerprint recognition and many researches are still going on to convert it into a cheaper and easy method of use. So, we can say that it’s an emerging technique. My project does not include this approach and so no further studies will be seen on this approach in my thesis.

CHAPTER 2.

SYSTEM DESIGN

2.1 SYSTEM LEVEL DESIGN:

A fingerprint recognition device is constituted of a fingerprint acquiring device for image acquisition step, minutia extractor for extraction of valuable minutiae and minutiae matcher for matching the minutiae as shown in FIG. 2.1.1

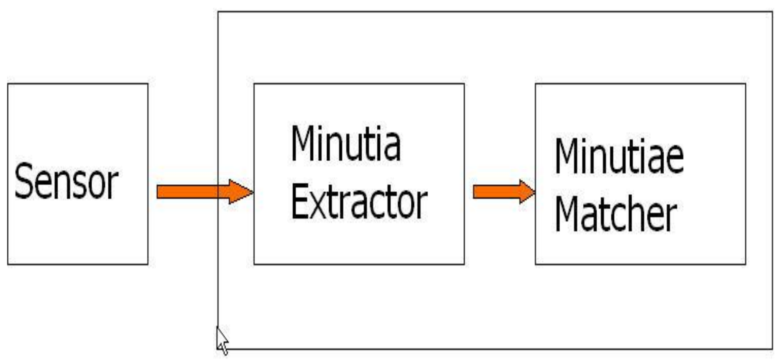


FIG 2.1.1 : Basic Model of Fingerprint Recognition system

For fingerprint acquisition step the acquiring devices which are optical or semiconductor sensors, are widely used. They exhibit high accuracy and efficiency unless and until user's finger is too dirty or dry. However, we are using an online database for the result verification in in our project.

We will go through the minutiae extractor and minutiae matcher modules in the next part where algorithm level design is explained and we will extend the discussion in other subsequent sections as well.

2.2 ALGORITHM LEVEL DESIGN

A minutiae extractor can be implemented as a three stage approach and is widely used by researchers. They are preprocessing, minutiae extraction and post processing stages (FIG2.2.1)

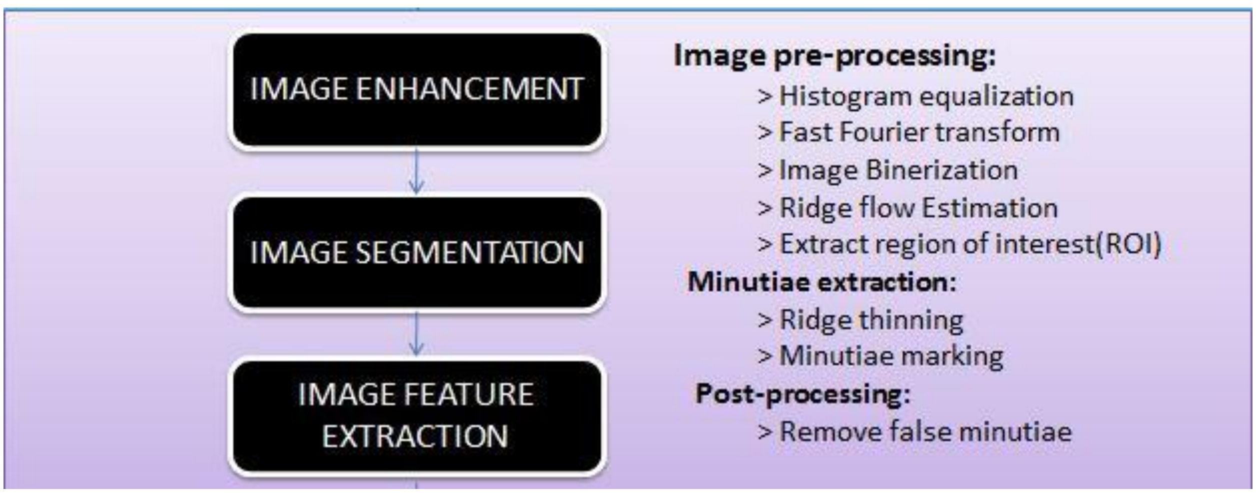


FIG 2.2.1 Minutiae Extractor

For the image preprocessing steps, we have used histogram equalization followed by Fast Fourier Transform to do the image enhancement and then image binerization is done by locally adaptive threshold method. The image segmentation has two parts, one is ridge flow estimation and other one is by the extraction of region of interest

(ROI) using morphological methods. Most of the pre-processing stages used here are a part of standard studies taken by many researchers but here they are carried in our project on basis of a lot of practical results taken by us.

For minutiae extraction stage, we take the help of a three thinning algorithm and we got a morphological thinning operation with a very fine thinning quality and high efficiency. Then the minutiae marking is a simple one just some regular MATLAB functions can handle them.

For the post-processing stages, a better and a very fine algorithm is required to remove false minutiae like H-breaks and isolated points etc.

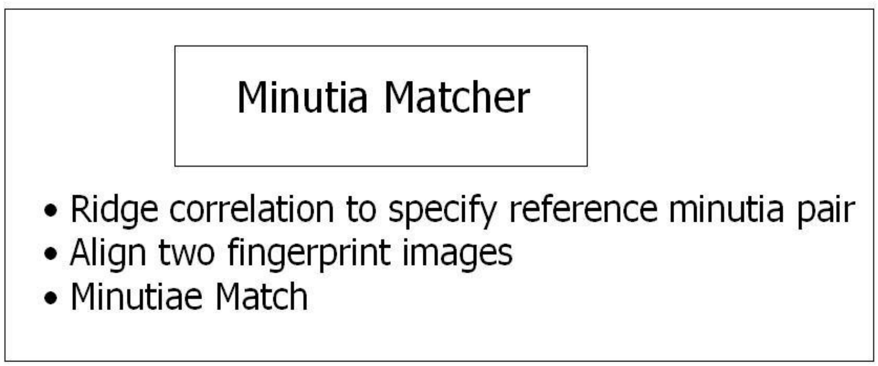


FIG 2.2.2 Minutiae matcher

The basic concept for minutiae matcher is to take a reference point or line then decide the origin for the co-ordinates and now translate and rotate the whole image in order to get the match. So, it first takes any two random minutiae as a reference pair and then matches their associated ridges. If, the ridges are matched very well then both the fngerprints are aligned and matching is done for all the extracted minutiae (FIG 2.2.2)

CHAPTER 3.

FINGERPRINT IDENTIFICATION SYSTEM

An identification system can be defined as the one which helps in identifying the individual from many people available. It generally involves matching available biometrics feature like fingerprint with the fingerprints which are already enrolled in the database.

3.1 HOW DOES FINGERPRINT RECOGNITION WORK?

In real life, the fingerprint images that are captured are not of optimum quality. So, we need to enhance their quality and remove noises. We also extract features likes minutiae and other details for matching. And if minutiae sets are matched with those in the database, we say it an identified fingerprint. And after matching we go for post-matching steps which includes retrieving details of the user from the online store and show it. A flowchart is shown in the next section.

3.2 FINGERPRINT IDENTIFICATION SYSTEM FLOWCHART

A complete methodology of our fingerprint identification system is briefly shown here in a flowchart. Each of whose steps are explained in later chapters FIG 3.2.1.

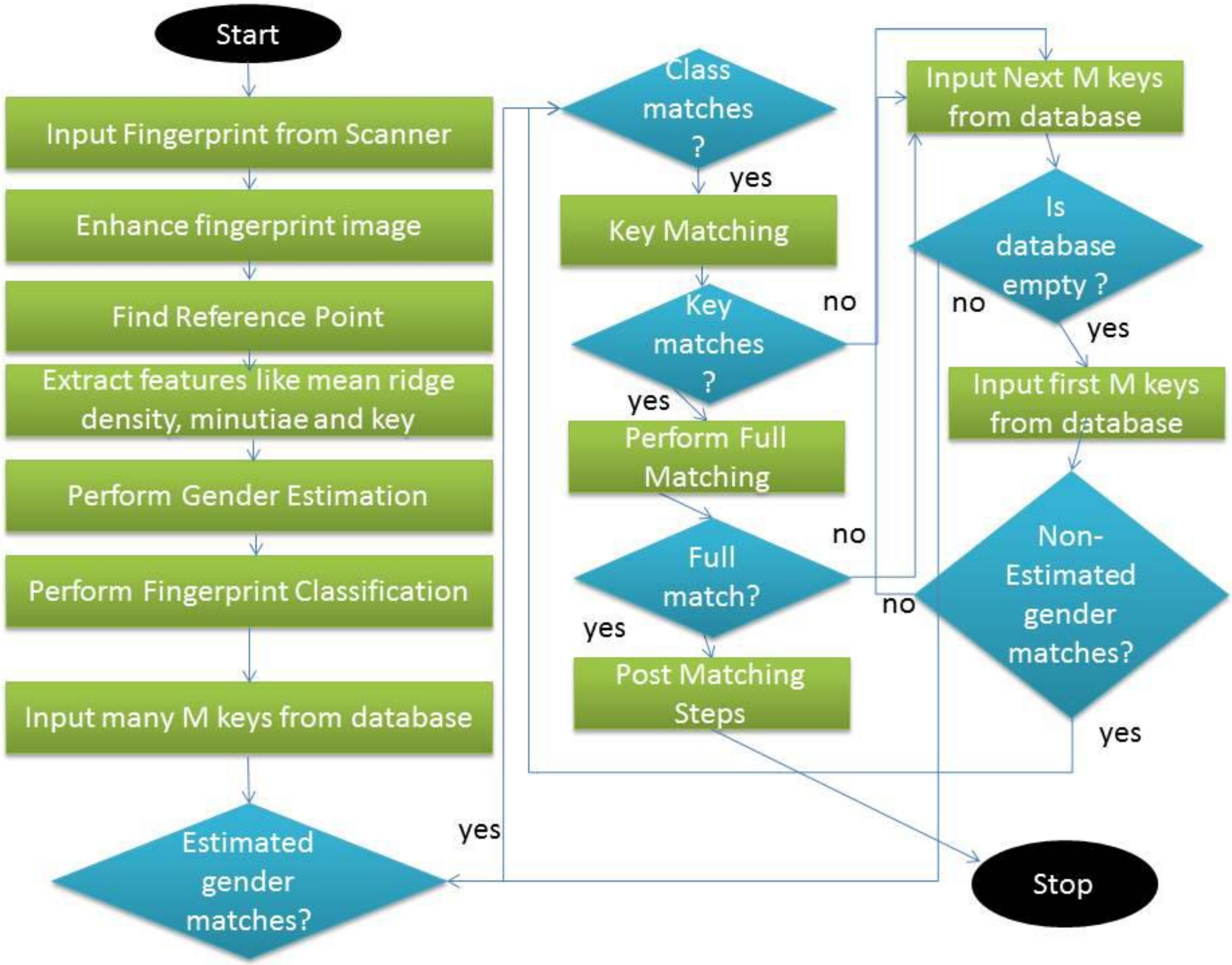


FIG 3.2.1FINGERPRINT IDENTIFICATION SYSTEM FLOWCHART

CHAPTER 4.

FINGERPRINT IMAGE PREPROCESSING

4.1 HISTOGRAM EQUALISATION

Histogram is a process that attempts to spread out the gray levels in an image so that they are evenly distributed across their range. It basically reassigns the brightness value of each pixel based on the image histogram. Histogram is a technique to produce more visually pleasing result across a wider range of images to produce as flat as possible histogram of the image.

(HISTOGRAM: The histogram of an image is a graphical plot of the number of occurrences of gray levels in the image against the gray level value.)

Procedure to perform histogram equalization:

1. Find the running sum of histogram values.
2. Normalize the value from step (1) by dividing by the total number of pixels.
3. Multiply the values from step (2) by the maximum gray-level value and round.
4. Map the gray level values to the results from step (3) using a one-to-one correspondence.

In MATLAB histogram equalization is done using an ingenious MATLAB function 'histeq (image)'. Below the figure shown for the original image histogram (FIG 4.1.1) and corresponding image histogram (FIG 4.1.2) after histogram equalization.

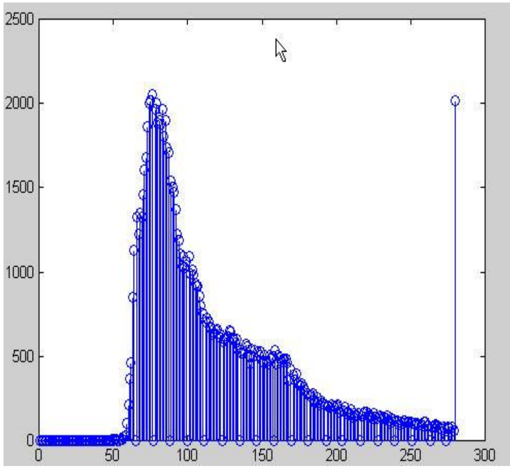


FIG 4.1.1 Original histogram

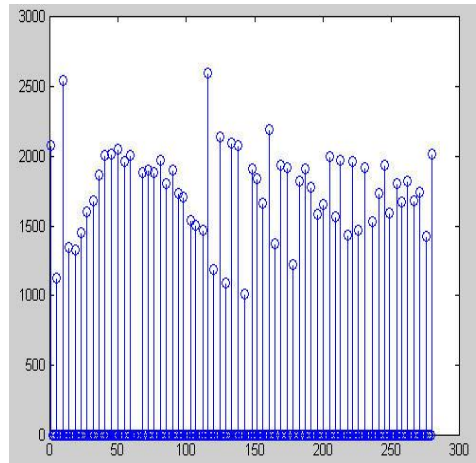


FIG 4.1.2 Histogram after histogram equalization

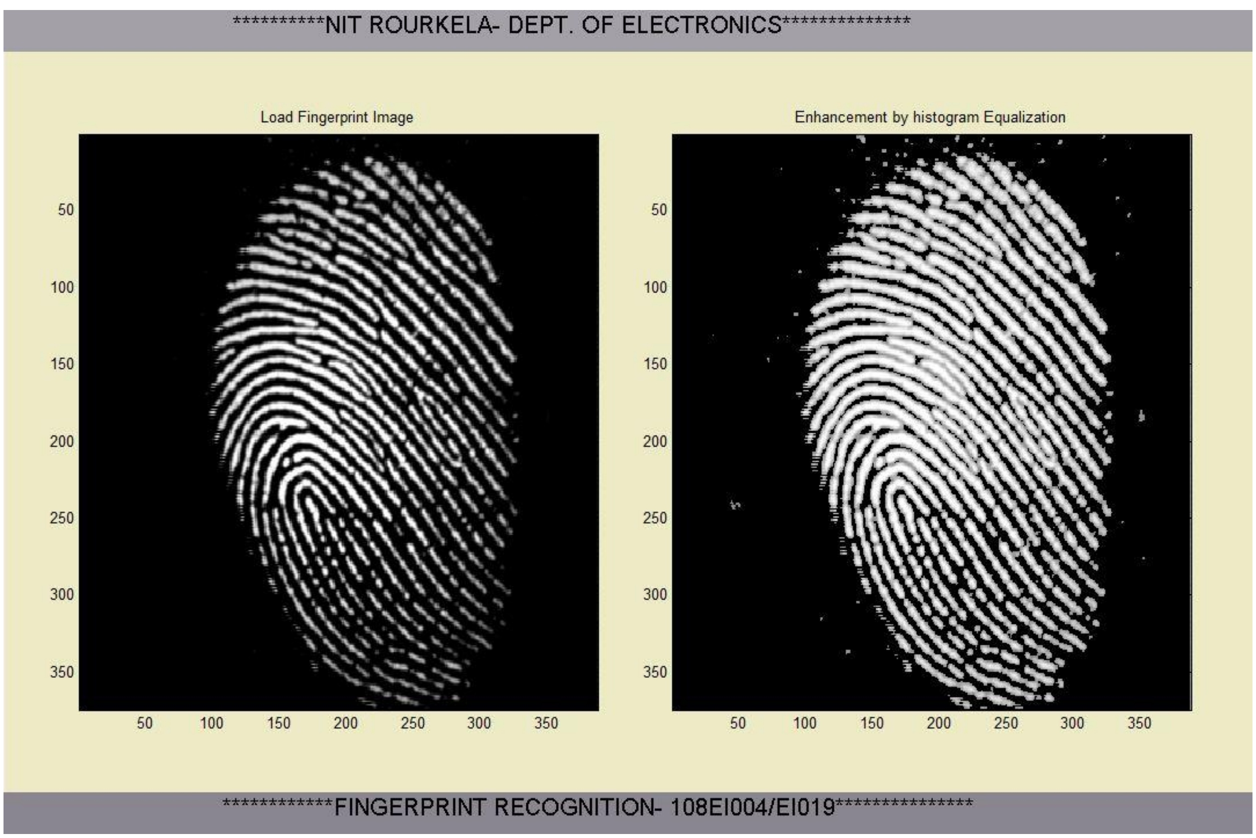


FIG 4.1.3 Histogram Enhancement (left: original image, right: enhanced image)

4.2 ENHANCEMENT THROUGH FOURIER TRANSFORM

In this enhancement, the image is divided into small processing blocks of 32by 32 pixels and then we perform the Fourier Transform on each block according to:

$$F(u,v) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y) \times \exp\{-j2\Pi \times (\frac{ux}{M} + \frac{vy}{N})\}$$

$$for\ u = 0,1,2, \dots \dots ., 31\ and\ v = 0,1,2, \dots, 31.$$

In order to enhance each block by its dominant frequencies, each block after FFT will be multiplied with its magnitude a set of times. Where magnitude can be given as: $abs(F(u,v)) = |F(u,v)|$

and the enhanced block will be based on :

$$g(x,y) = \mathrm{F}^{-1}\{F(u,v) \times |F(u,v)|^k\}$$

Where $\mathrm{F}^{-1}(\mathrm{F}(u,v))$ is given by:

$$f(x,y) = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} F(u,v) \times exp\left\{j2\Pi \times \left(\frac{ux}{M} + \frac{vy}{N}\right)\right\}$$

$for\ x = 0,1,2, \dots .., 31\ and\ y = 0,1,2, \dots \dots, 31$

The k in the formulae is a constant which is determined experimentally, here we will choose the k value = 0.45 by some experiments over fingerprints. Suppose, if we have a higher 'k' then the appearance of the ridges will be improved and it will fill up the small holes in ridges but, if have a very higher 'k', then it can result into false joining of ridges. Hence, termination minutiae might become bifurcation minutiae. FIG 4.2.2 represents the image after FFT enhancement where FIG 4.2.1 is the image after histogram equalization

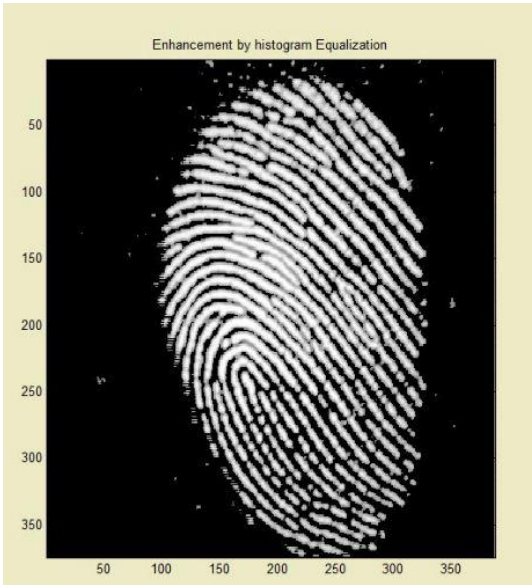


FIG 4.2.1 Histogram equalized image

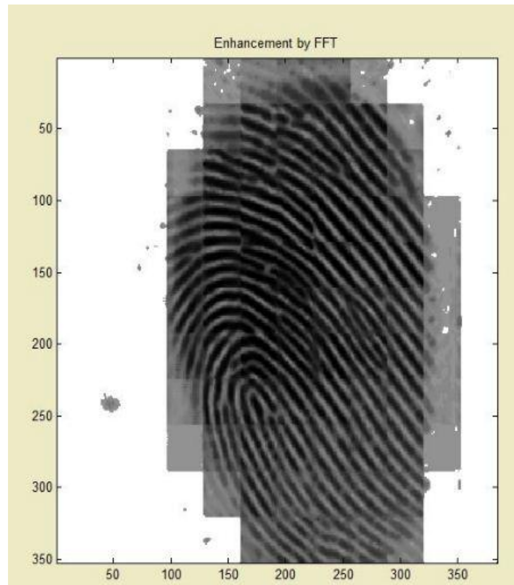


FIG 4.2.2 Image after FFT operation

As, the value of ‘k’ is determined experimentally here are some figures which supports the ‘k’ value for being 0.45. Although, it is determined after a lot number of experiments.

The enhanced image after FFT is improved as some falsely broken points on ridges are connected and some spurious connection between ridges are removed. The each block operation obviously create some side-effects, but it is not harmful on further operations as the image quality after consecutive binerization becomes quite good and the side-effect becomes no severe.

FIG 4.2.3 original image

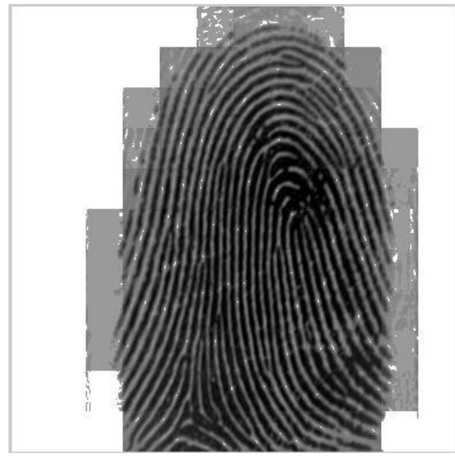


FIG 4.2.4 k=0.1

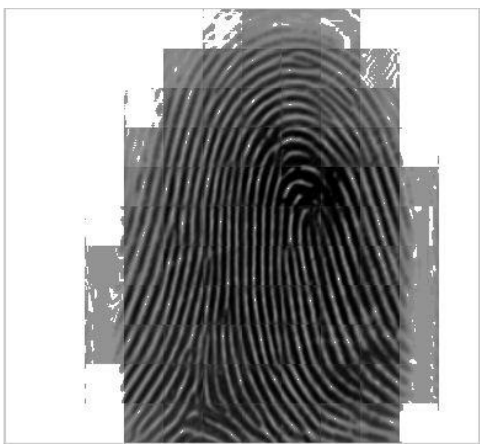


FIG 4.2.5 k=0.4

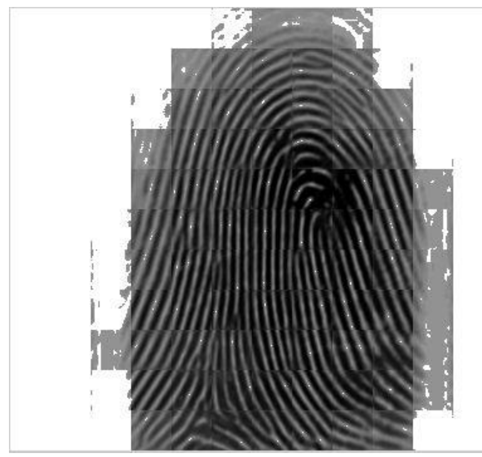


FIG 4.2.6 k=0.45

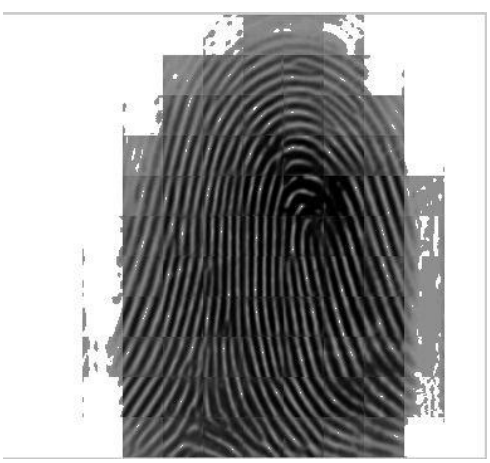


FIG 4.2.7 k=0.5

FIG 4.2.8 k=1.0

4.3 FINGERPRINT IMAGE BINARIZATION

Fingerprint image binarizationis done to transform a 8-bit gray image to a 1-bit binarized image where 0-value holds for ridges and 1-value for furrows. And after the binarization operation ridhes are highlighted with black color and furrows are highlighted with white color.

Here, we will use a locally adaptive binarization method called as 'adaptive thresholding' to binarize the fingeprint image. In this method we transform the gray level to 0 if it is below threshold value and to 1 if it is above threshold value. The threshold value is the mean taken from the gray level of the current block(16*16) to which the pixel belong. [FIG 4.3.1]

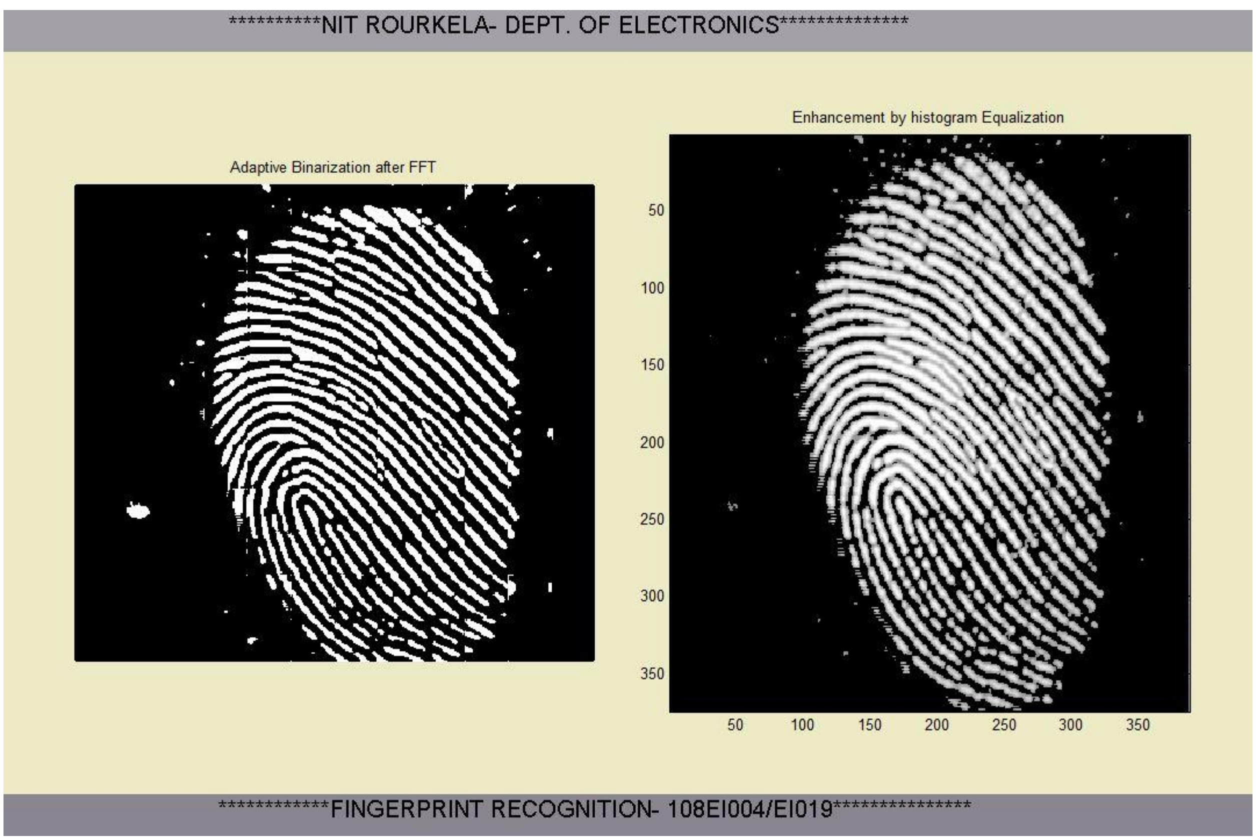


FIG 4.3.1 binarised image (left), histogram equalised image (right)

4.4 FINGERPRINT IMAGE SEGMENTATION

As for our aim only region of interest is the useful part which needs to be recognized for each and every fingerprint image. Here, the image area without effective furrows and ridges will be first discarded from the image since it has only background information. Then we will sketch out the bound of the remaining effective area since bound region minutiae produces confusion with the spurious minutiae that are generated out of the sensor.

To get the ROI we use a two-step method. The first step constitutes 'block direction estimation' and 'direction variety check', whereas the second step is done using some morphological operations.

1. **BLOCK DIRECTION ESTIMATION**

1.1 Here, block direction for each pixel had been estimated for the fingerprint image with a 16*16 pixel in size. The algorithm is as below:

I. The gradient value along x-direction (g_x) and y-direction (g_y) for each pixel is calculated. For this task two 'Sobel filters' are used.

II. For each block ,to get the Least Square Approximation of the block direction the following formula is used.

$$tan2\beta = 2 \times \sum\sum(gx \times gy)/\sum\sum(\mathrm{gx}^2 - \mathrm{gy}^2)$$

The formula is quite easy to understand if the gradient value along x and y-direction are represented as cosine and sine value. So the tangent value of the block direction obtained in sine and cosine terms is

$$\tan 2\beta = (2\sin\theta \times \cos\theta)/(\cos^2\theta - \sin^2\theta)$$

1.2 After the estimation of each block direction, the blocks without significant information of ridges and furrows are discarded according to the following formula:

$$E = \{2 \times \sum\sum(gx \times gy) + \sum\sum(\mathrm{gx}^2 - \mathrm{gy}^2)\} / \{W \times W \times \sum\sum(\mathrm{gx}^2 + \mathrm{gy}^2)\}$$

For each block, if E is below a certain threshold value, then the block is considered as a background block.

The direction map is shown below.

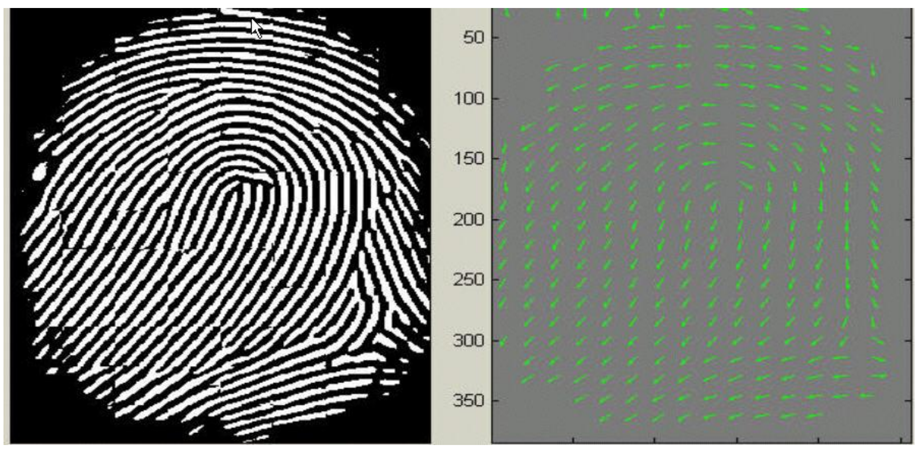


FIG 4.4.1 direction flow estimate. Binarized image (left) , direction map (right)

2. ROI EXTRACTION BY MORPHOLOGICAL OPERATION

Two morphological operations ‘OPEN’ and ‘CLOSE’ are adopted. The OPEN operation expand images and remove peaks which are generally introduced by background noise. The CLOSE operation usually shrink images and eliminates small cavities .

The bound region is obtained after subtraction of closed area from the opened area. The morphological operation are done using the built in morphological operations

```
bwmorph(x,'close')
bwmorph(y,'open')
```

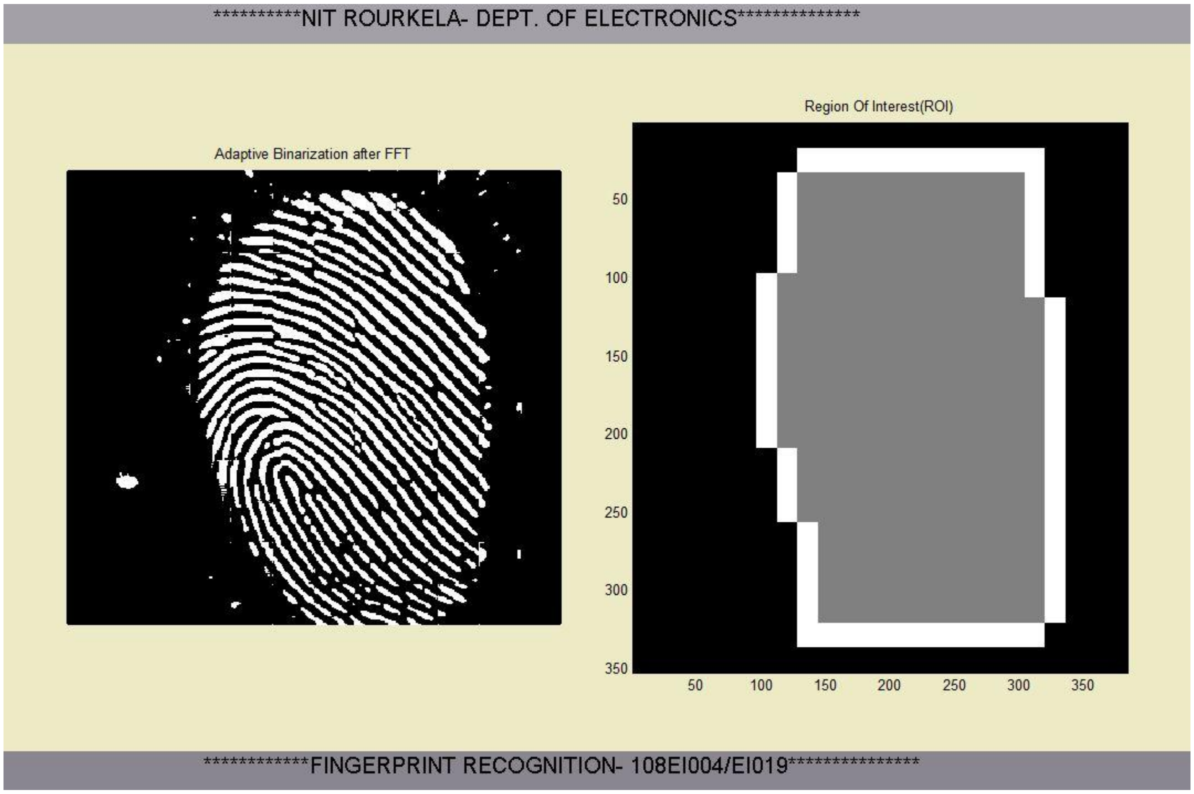


FIG 4.4.2 ROI with bound

CHAPTER 5. MINUTIAE EXTRACTION

5.1 FINGERPRINT RIDGE THINNING

Thinning is the process of reducing binary objects or shapes to strokes whose width is one pixel wide. Here in fingerprint recognition thinning is done to thin the ridges so that each is one pixel thick. In each scan of the fingerprint image, the algorithm removes the redundant pixels in small image window (3x3).In our algorithm, for thinning purposes we had invoked an inbuilt morphological operation in MATLAB.

Bwmorph (image, 'thin' ,Inf)

n=Inf, thins objects to lines (i.e. one pixel wide).

The thinned image is then processed by three other morphological operations in order to remove H-breaks (H-connected foreground pixels) and spur pixels (isolated points and spikes).Here also we had used in-built morphological operations.

Bwmorph (image, 'h-break');

Similarly for spur pixels

Bwmorph (image, 'spur')

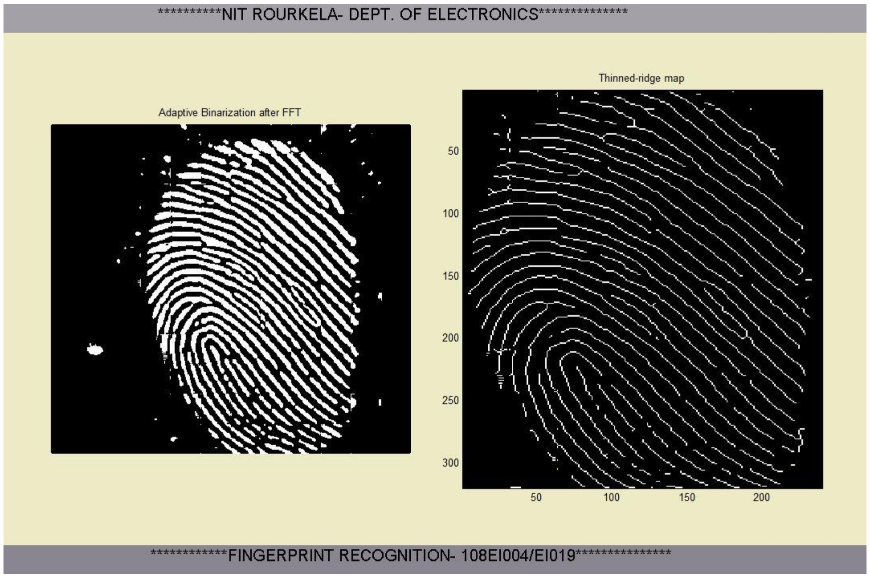


FIG 5.1.1 (a) Binarized Image (b) Thinned Ridge Image

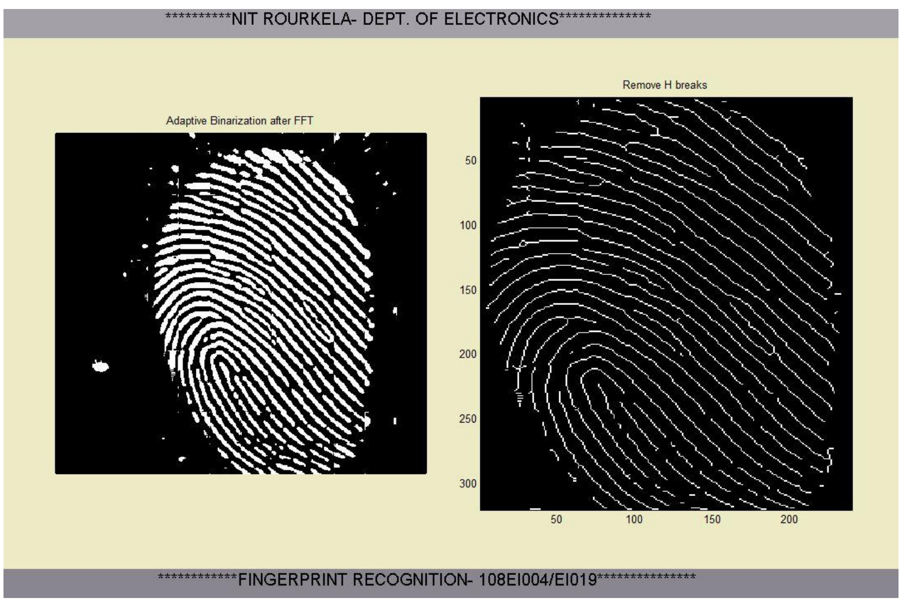


FIG 5.1.2 (a) Binarised Image, (b) removed H-breaks from thinned image

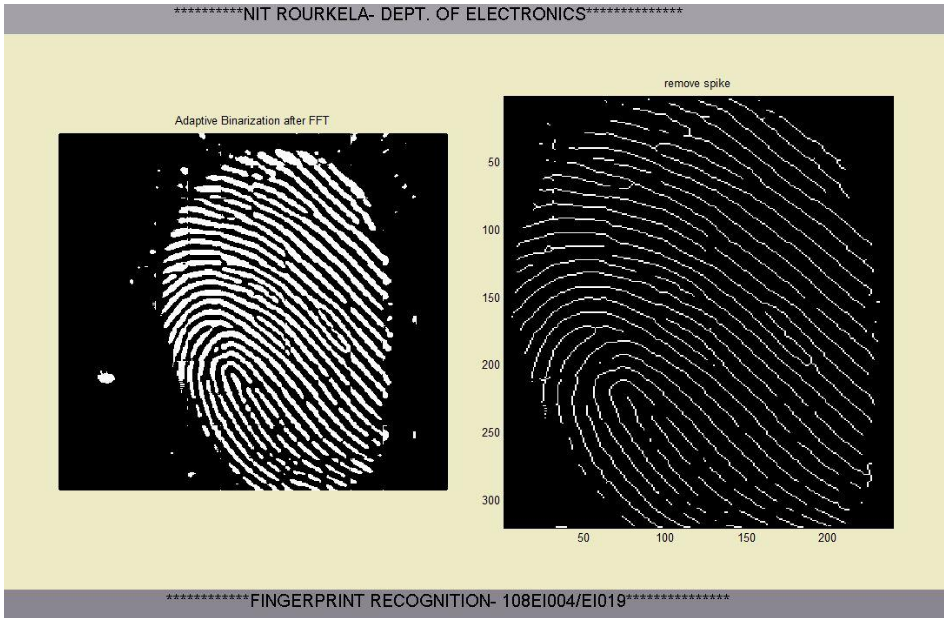


FIG 5.1.3 (a) Binarized Image, (b) Removed spikes after removing H-breaks

5.2 MINUTIA MARKING

After the thinning operation, marking of minutia points becomes relatively easy .For minutia marking generally a 3x3 window is taken, if the central pixel is 1 and has three 1 value neighbors in its 8-connected neighborhood, then the central pixel is a ridge bifurcation and if the central pixel is 1 and has one has only one 1-value in its 8-connected neighborhood, then it is a ridge end.

0	1	0
0	1	0
1	0	1

FIG 5.2.1 RIDGE BIFURCATION

0	0	0
0	1	0
0	0	1

FIG 5.2.2 RIDGE ENDING

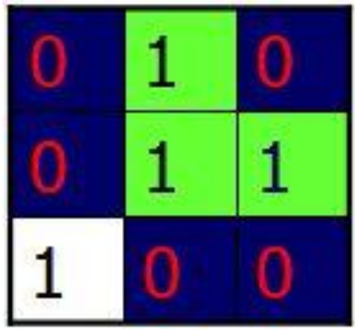


FIG 5.2.3 TRIPLES COUNTING BRANCH

The above figure shows a special case where a genuine branch is triple counted.

Suppose both the uppermost pixel and the rightmost pixel with value 1 have a neighbor outside the 3x3 window, and then the two pixels would be marked as branches too. But, actually only one branch is present in the small region. So a check routine is done considering that none of the neighbors of a branch or branches are added.

At this stage the average inter ridge width (D) is calculated. The average inter ridge width (D) is the average distance between 2 neighboring ridges. The calculation of D is very simple. A row of pixels of the thinned ridge image is scanned and all the pixels having value 1 are added up. Then, the row length is divided by the above summation in order to get an inter ridge width. For more accuracy, the scan is done for all rows and column in the above similar way and then all the inter ridge widths are averaged to get D.

After minutia marking, all the thinned ridges are labeled with an unique ID for further processing. The labeling is done using the inbuilt Morphological operation: ***bwlabel().***

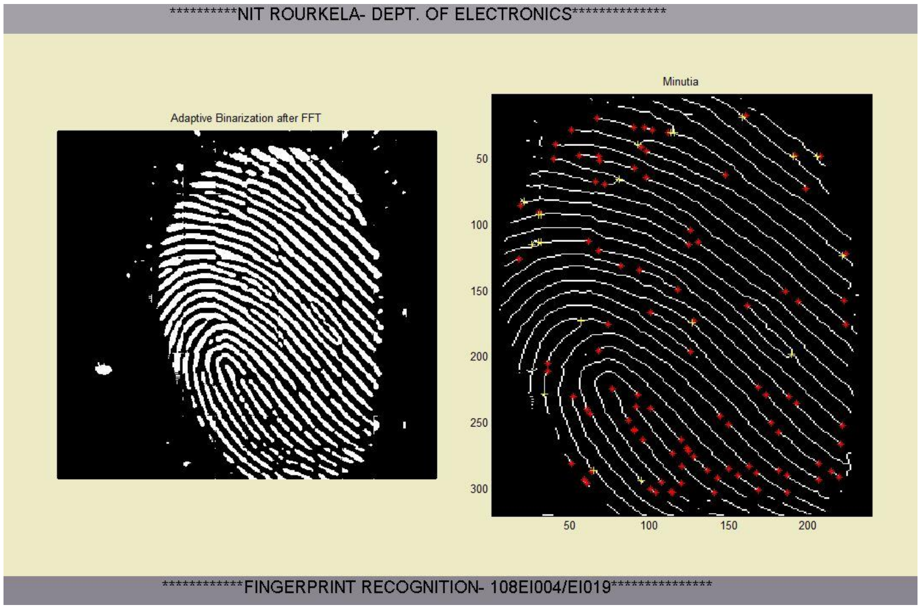


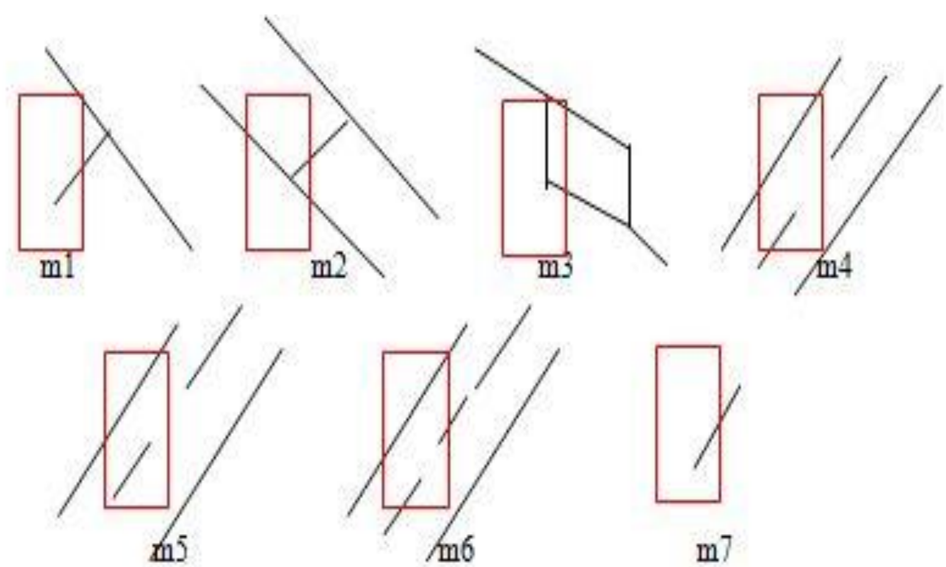
FIG 5.2.4 (a) Binarized image, (b) Minutiae marked on thinned image

CHAPTER 6. MINUTIA POSTPROCESSING

6.1 FALSE MINUTIA REMOVAL.

The pre-processing stage of a fingerprint image does not remove all the errors. For instance, false ridge breaks and ridge cross-connections due to insufficient amount of inking and over inking are not completely eliminated. Actually all the previous stages themselves occasionally introduce some errors which further lead to spurious minutia. This false minutia significantly affects the accuracy of matching only if they are regarded as genuine minutia. So, some mechanisms of removing these false minutiae are essential in order to keep the fingerprint verification system effective.

There are several types of false minutiae, but here in our project we have considered only seven types of false minutiae.



1) In the m1 case a spike pierces into a valley.
2) In m2 a spike falsely connects two ridges.
3) In m3 two near bifurcations present in the same ridge.
4) In the m4 case we have two ridge broken points separated by a very short distance and same orientation.
5) m5 is almost similar to that of m4 case with an exception that one part of the broken ridge is so short that it's another termination is generated.
6) m6 is the extension of the m4 case with an extra property that a third ridge is found in between two parts of a broken ridge.
7) m7 has a very short ridge found in the threshold window.

Our approach for removal of false minutiae

1. If the distance between a bifurcation and a termination is less than D and both the minutia are in the same ridge(m1 case) ,then both of them are removed .Here D is the average inter-ridge width which represents the average distance between two parallel neighboring ridges.
2. If two bifurcations are present in the same ridge and the distance between them is less than D, then both the bifurcations are removed. (m2, m3 cases).
3. If the distance between two terminations is less than D and their directions are almost coincident with only a small angle variation. And they satisfy the condition that no other termination is located in between the two terminations. Then, both the terminations are regarded as false minutia and is considered as part of a broken ridge, hence removed. (case m4,m5, m6).
4. If the distance between two terminations of a very short ridge is less than D ,then it is considered as a false minutia and is removed

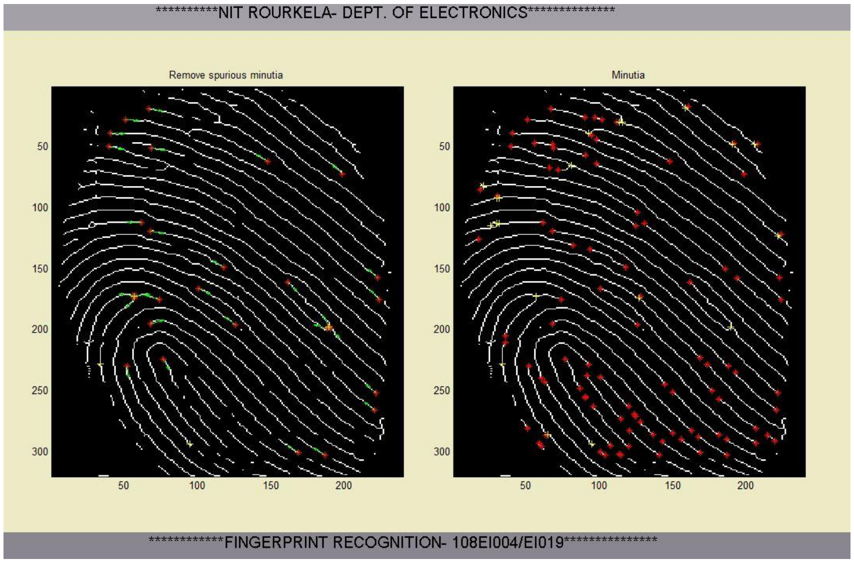


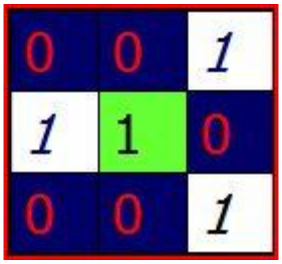
FIG 6.1.1 (a) image after removal of false minutiae, (b) Image with all marked minutiae

6.2 UNIFY TERMINATIONS AND BIFURCATIONS

Various data acquisition conditions like impression pressure can change one type of minutia into another. So we have adopted the unification representation for ridge termination and bifurcation. In this approach we need to characterize a minutia into the following parameters.

1) x-coordinate
2) y-coordinate
3) orientation

The orientation of a ridge end can be easily calculated as it has a single direction. But the orientation calculation of a bifurcation is quite difficult as all the three ridges of a bifurcation have their own directions. The 3 new terminations are the neighboring pixels of a bifurcation, and each of the ridges connected before is now having a termination.



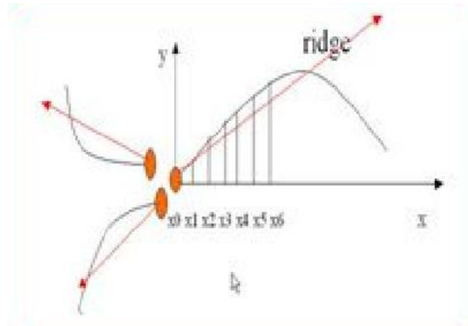


FIG 6.2.1 a bifurcation to three termination, (a) Three neighbors become terminations, (b) Each termination with its own orientation

Assuming the orientation of a termination be (tx,ty) ,the method involved in calculating the orientation is described below:

1) Track a ridge segment of length L and which starts at the termination. Take the summation of all the x-coordinates of points on the ridge segment.
2) The above summation is divided by L to get Sx.Then Sy is calculated in the similar manner.

Now the direction of a termination is calculated by the formula

$$tan\ \beta = (Sy - ty)/(Sx - tx).$$

CHAPTER 7. MINUTIA MATCH

The minutia details of two fingerprints are obtained using the above procedures and they are matched using the minutia match algorithm. Alignment based match algorithm is used in our project. It comprises of two stages:

1) Alignment stage
2) Match stage

An iterative ridge alignment algorithm is first used to align one set of minutia with respect to another and then an elastic match algorithm is carried out to count the number of matching minutia pairs.

7.1 MINUTIAE ALIGNMENT

1) Let I1 and I2 represent two set of minutiae given by

$$I_1 = \{m_1, m_2, m_3, \ldots\ldots m_n\} \text{ where } m_i = \{x_i, y_i, \theta_i\}$$

$$I_2 = \{m_1', m_2', m_3', \ldots\ldots m_N'\} \text{ where } m_i' = \{x_i', y_i', \theta_i'\}$$

One minutia from each set is chosen and the ridge correlation factor is calculated in between them. The ridges associated with each minutia are represented by a series of x-coordinates (x1,x2,x3,x4,....,xn) of the points on the ridges. Sampling is done per ridge length L from the starting of the minutia point where L is the average inter ridge width and n is set to 10 unless total ridge length is less than that of 10*L.

The similarity between the two ridges is calculated using the following formula

$$S = \sqrt{\frac{\sum_{i=0}^{m} xi \times Xi}{\sum_{i=0}^{m} xi^2 \times Xi^2}}$$

Where (x1,x2,x3,...,xn) and (X1,X2,X3,...,Xn) represents two sets of x-coordinates for 2 minutia chosen and m is one of the minimal value of n and N. If the similarity score is above 0.8 then go to step 2 otherwise continue the process of matching for next 2 minutiae.

2) In the second stage each set of minutia is transformed with respect to the reference minutia and then matched in a unified x-y coordinate.

Suppose M(x, y, θ) be the reference minutia derived from step 1(say from I1). Then for each minutia, translation and rotation of all other minutiae is done w.r.t the reference minutia M according to the following formula.

$$\begin{pmatrix} xi\_new \\ yi\_new \\ \theta i\_new \end{pmatrix} = \begin{pmatrix} cos\theta & -sin\theta & 0 \\ sin\theta & cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} xi - x \\ yi - y \\ \theta i - \theta \end{pmatrix}$$

Now the new coordinate system has its origin at reference minutia M and the new x-axis coincides with the direction of the minutia M. Scaling effect is not taken into account by assuming that two fingerprints taken from the same finger have almost the same size.

Transformed sets of minutiae (I_1’ & I_2’) are obtained.

7.2 MINUTIAE MATCHING

Elastic string match algorithm is being used to find the number of matched minutia pairs present in I_1' & I_2'.

According to elastic string match algorithm a minutia in I_1'(say m_i) and a minutia in I_2' (say m_j) are said to be "matching ",if the spatial difference sd between them is smaller than a given tolerance value r_0 and their direction difference(dd) is smaller than an angular tolerance θ_0 i.e. their direction is almost coincident.

$$sd = \sqrt{((xi - xj)2 + (yi - yj)2)} \leq r0$$

$$dd = min\left(|\theta i - \theta j|, 360 - |\theta i - \theta j| \right) \leq \theta 0$$

Let $mm(mi, mj)$be an indicator function which returns 1 in case minutiae m_i and m_j match according to the above equations.

$$mm(mi, mj) = \begin{cases} 1, & sd(mi, mj) \leq ro \text{ } and \text{ } dd(mi, mj) \leq \theta o \\ 0, & otherwise \end{cases}$$

Now, the total number of matched minutia pair is given by,

$$num(matched\ minutae) = \sum mm(mi\ , mj)$$

And final match score is calculated by the formula,

$$match\ score = \frac{num(matched\ minutiae)}{max(num\ of\ minutae\ in\ I1, I2)}$$

CHAPTER 8. RESULTS

8.1 Performance Evaluation Index

Two indexes are well accepted for determining the performance of a fingerprint recognition system:

- **False Rejection Rate(FRR):-** For an image database, each minutia sample is matched against the remaining samples of a particular finger to compute the FRR.A system's FRR is basically calculated by the following formula.

$$(\%)FRR = (FR/N) * 100$$

FR=number of false rejections.

N=number of samples.

- **False Acceptance Rate (FAR):-**Also in a database the first sample of each finger is matched with the first sample of the remaining fingers in order to compute the FAR. A system's FAR is calculated by the formula.

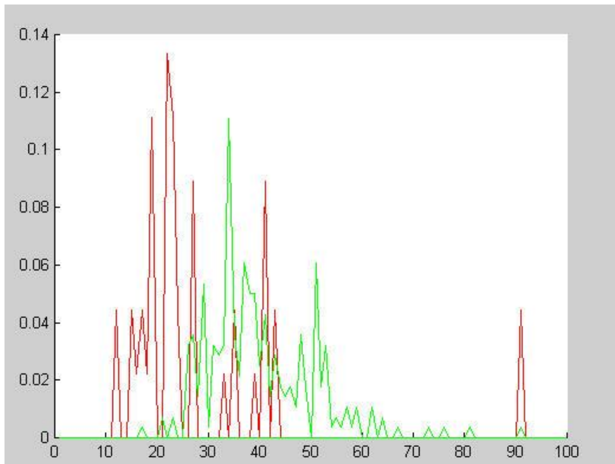
$$(\%)FAR = (FA/N) * 100$$

FA=number of cases of false acceptances

N=number of samples.

8.2 Experimentation Results

In our experiments distribution curve is obtained which gives an average correct match score of around 33 and average incorrect match score of around 25 on the database chosen.



Red: Incorrect

Green: Correct

FIG 8.2.1 Distribution of correct scores and incorrect scores

In our experiment, the FAR value obtained ranges from 25-30% approximately. Thus at a threshold score of 33 the verification rate of the algorithm is around 70 to 75%.

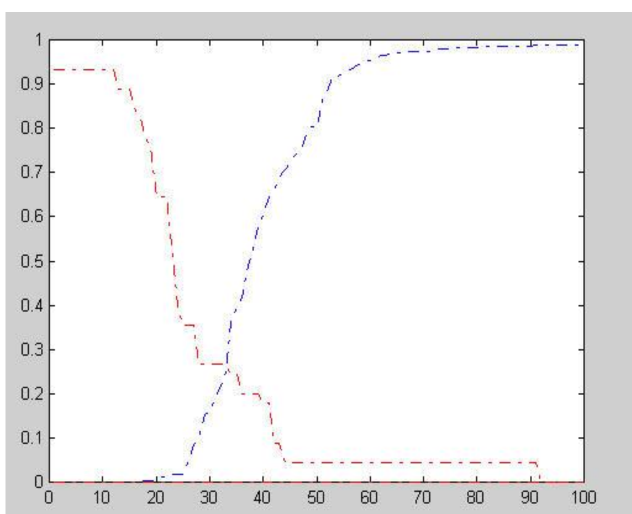


FIG 8.2.2 FRR and FAR curve (Red: FAR, BLUE: FRR)

CONCLUSION

We have grouped many methods in our project to make minutiae extractor and minutiae matcher and this grouping of methods comes from a wide range of research papers studies and many journals play a vital role in gathering those studies and getting a conclusion to get an efficient recognition system. We have started it from the use of a biometric device to turn it into an efficient biometric fingerprint recognition instrument.

The hardware part is not illustrated here but the algorithm and basic concept behind each step are given with a priority study concept. And all the algorithm are coded using MATLAB which finally gives a 'GRAPHICAL USER INTERFACE' where we can watch the processes happening.

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STEPS OF GRAPHICAL USER INTERFACE:

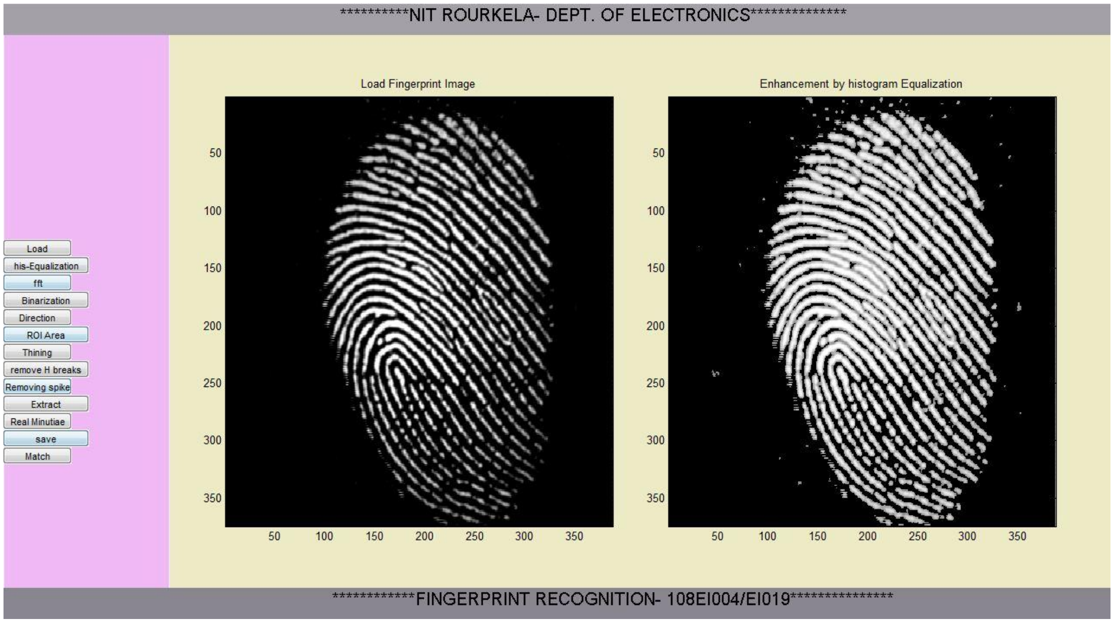

FIG: HISTOGRAM EQUALISATION

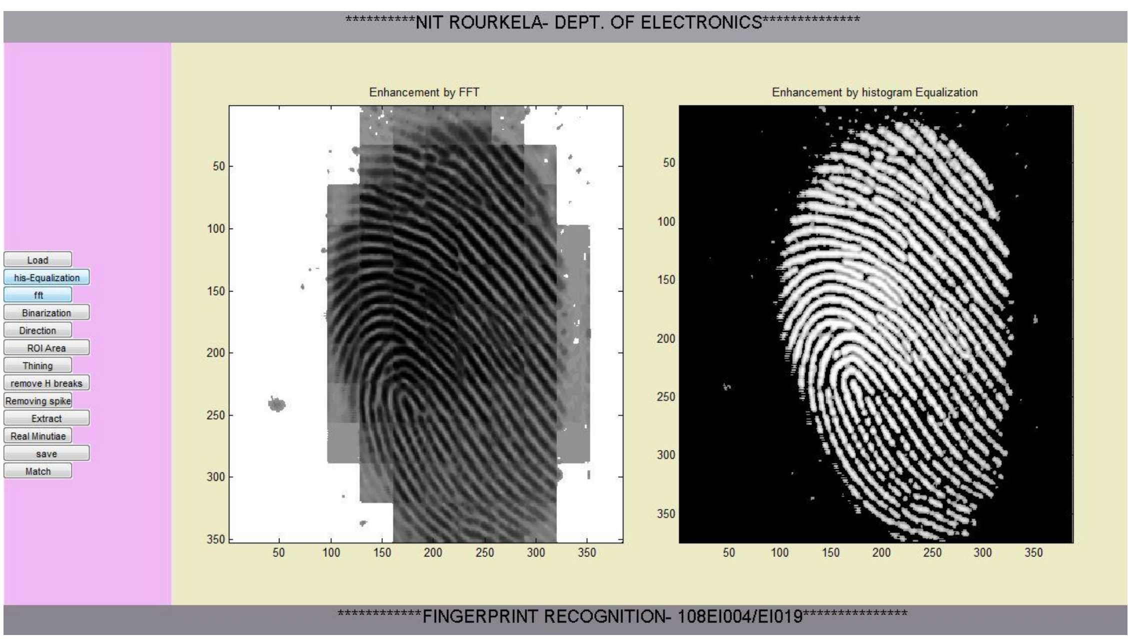

FIG: FFT TRANSFORM

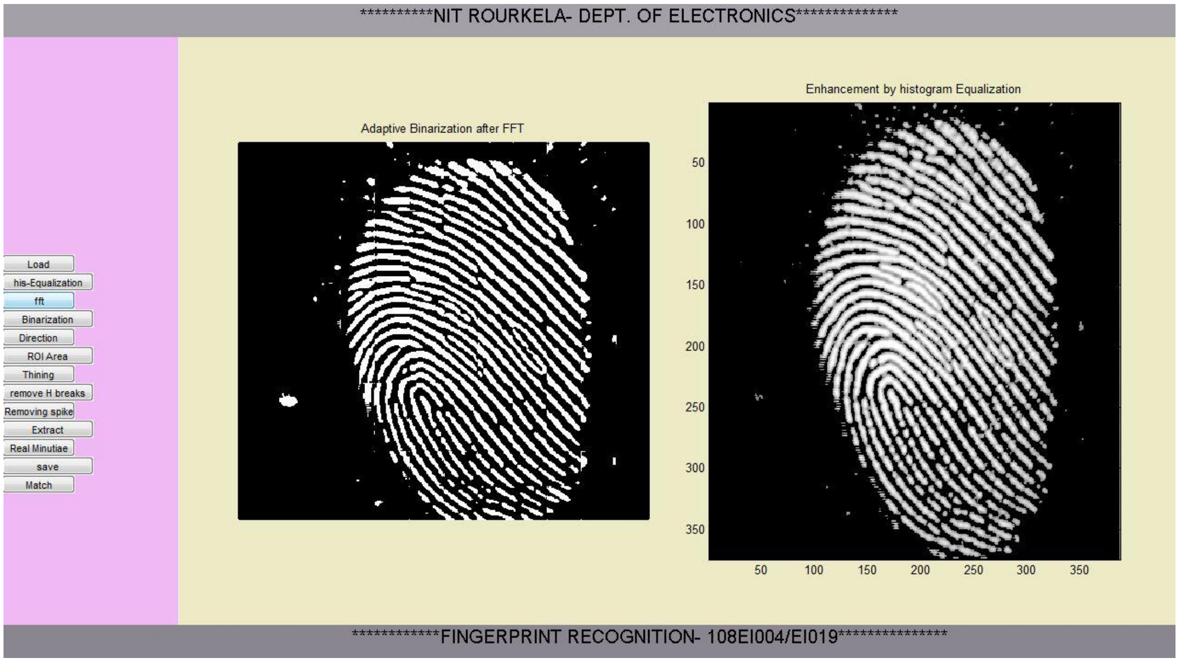

FIG: BINARIZATION AFTER FFT

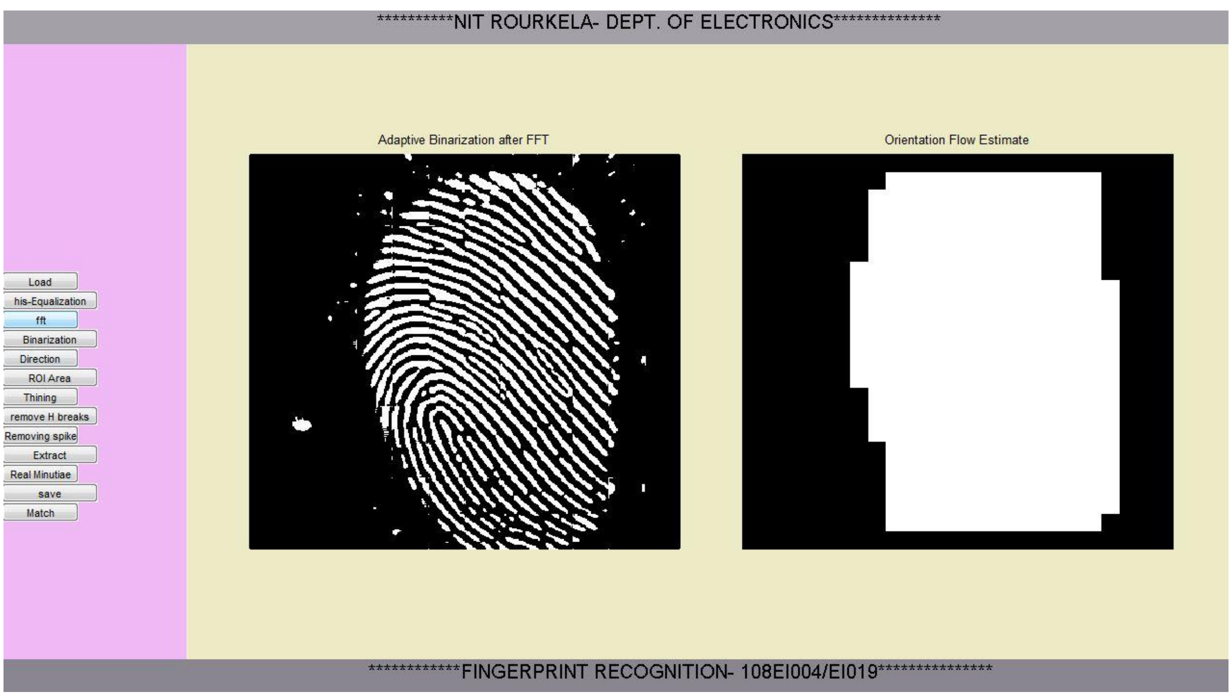

FIG: DIRECTION FOR THE BINARIZED IMAGE

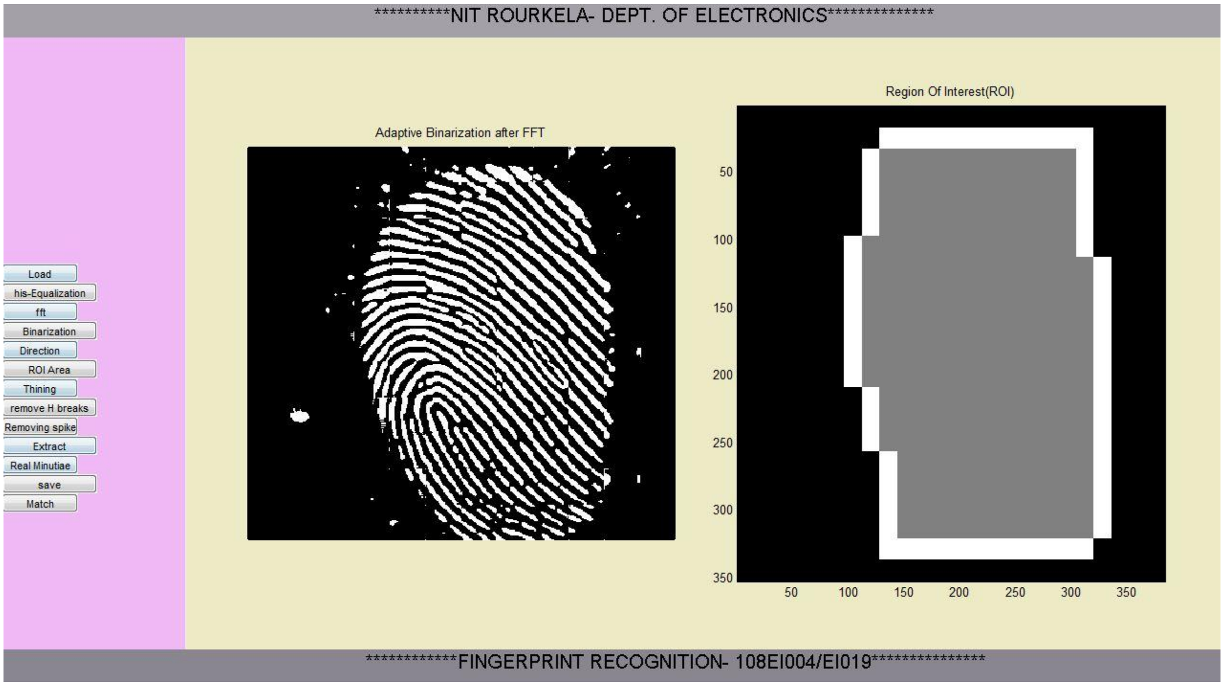

FIG : REGION OF INTEREST + BOUND OF BINARIZED IMAGE

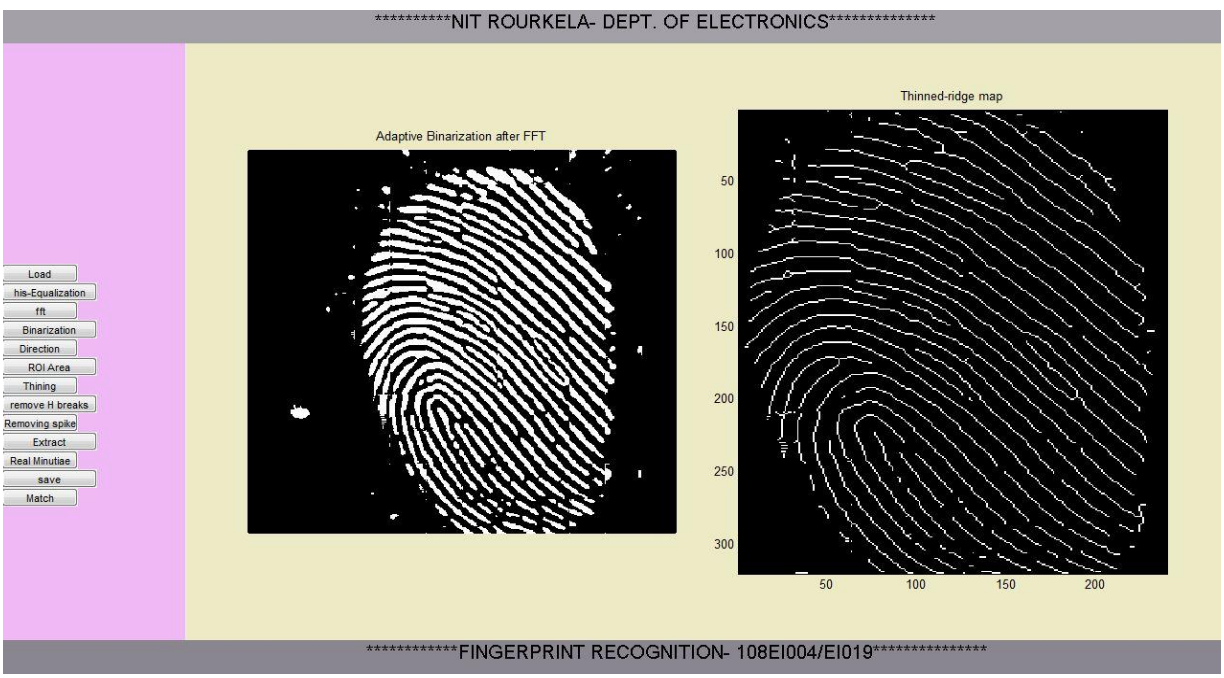

FIG: THINNING OF BINARIZED IMAGE

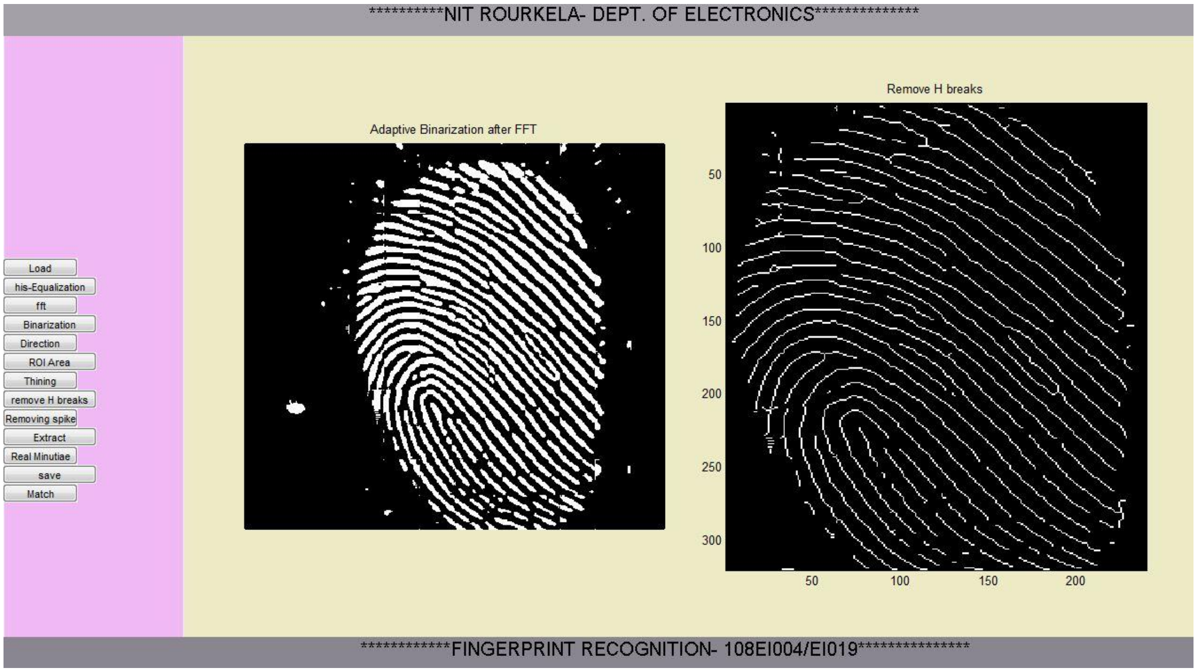

FIG: REMOVING H-BREAKS OF THINNED IMAGE

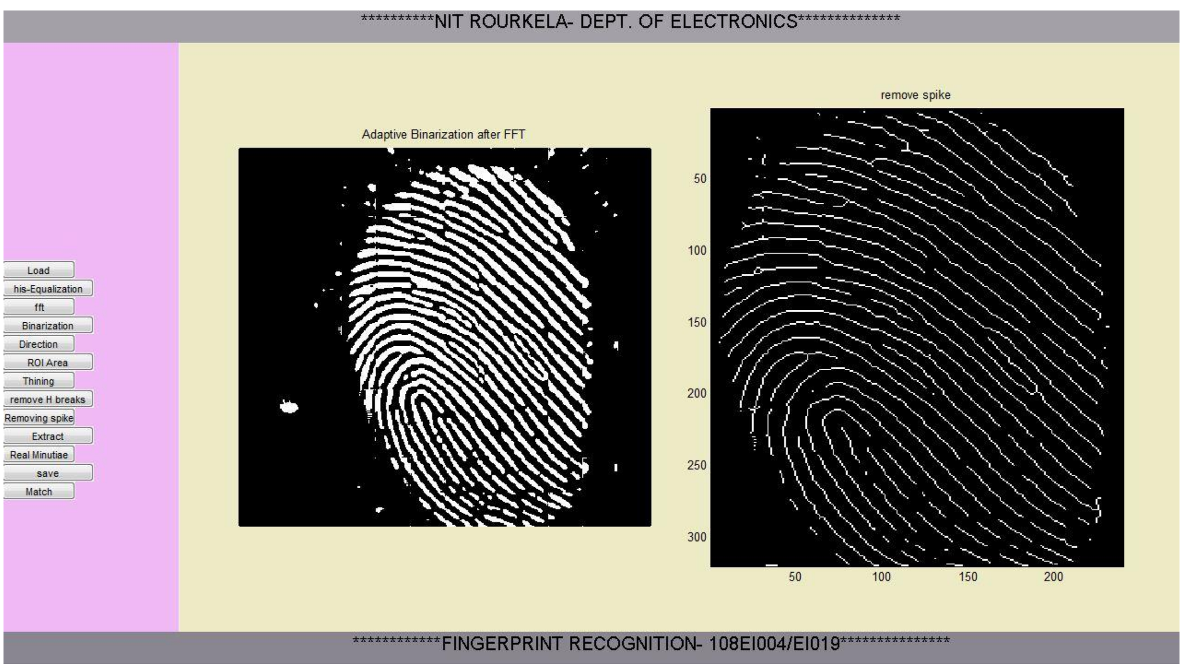

FIG: REMOVING SPIKES AND ISOLATED POINTS

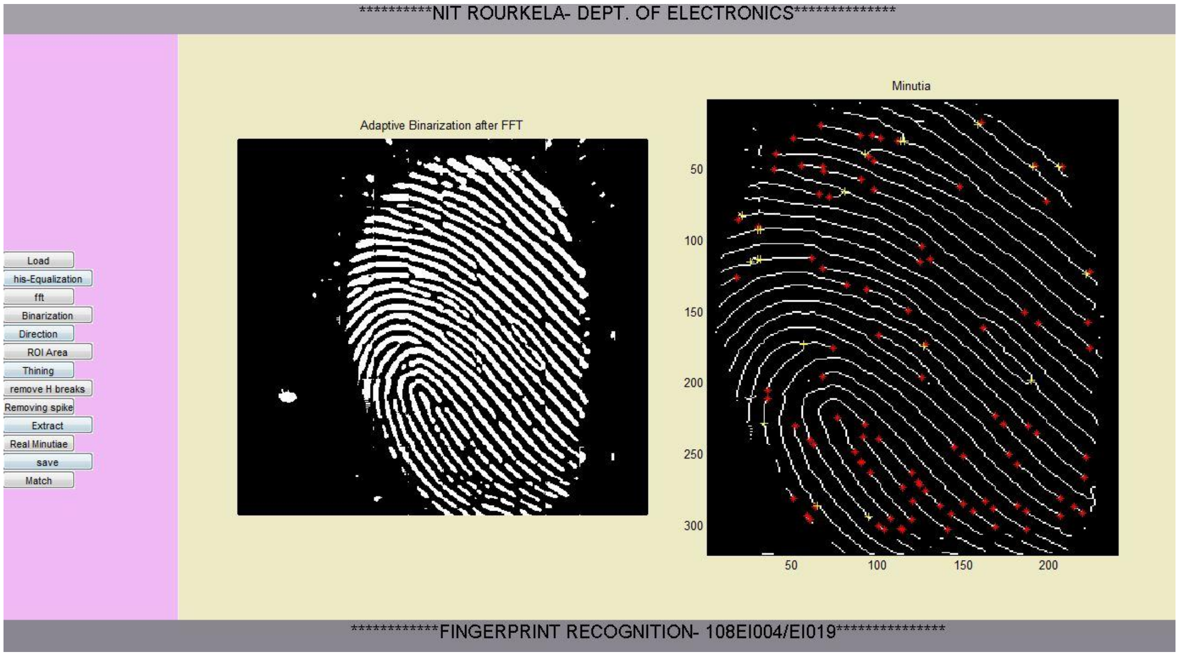

FIG: MINUTIAE EXTRACTION

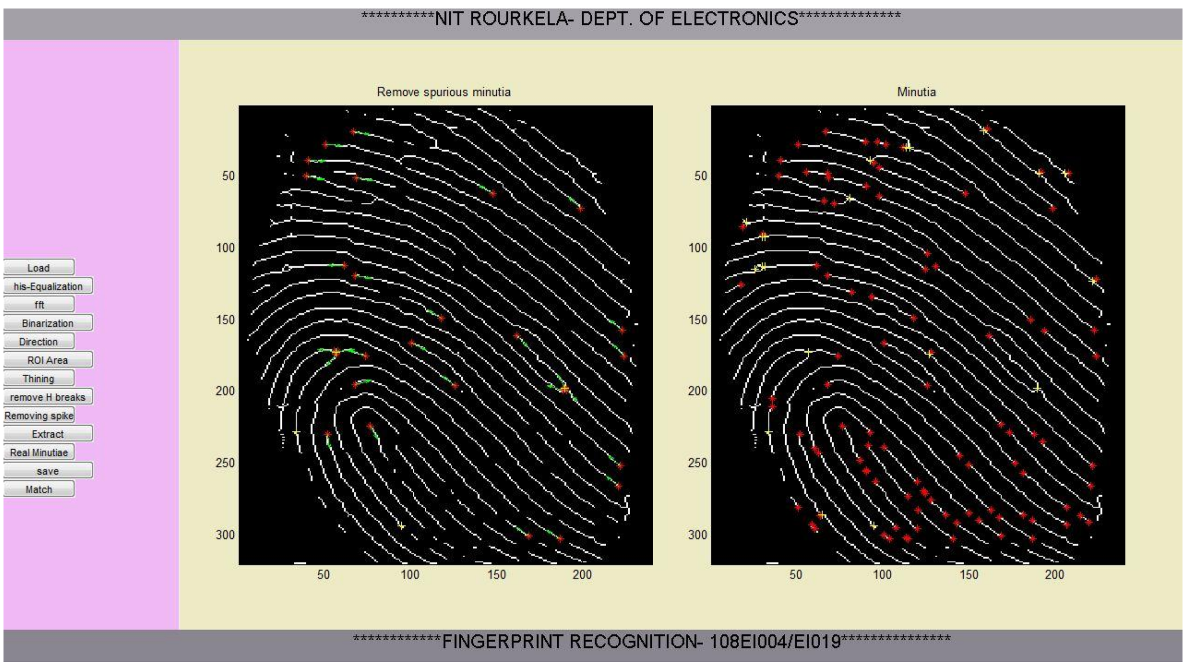

FIG: REAL MINUTIAE

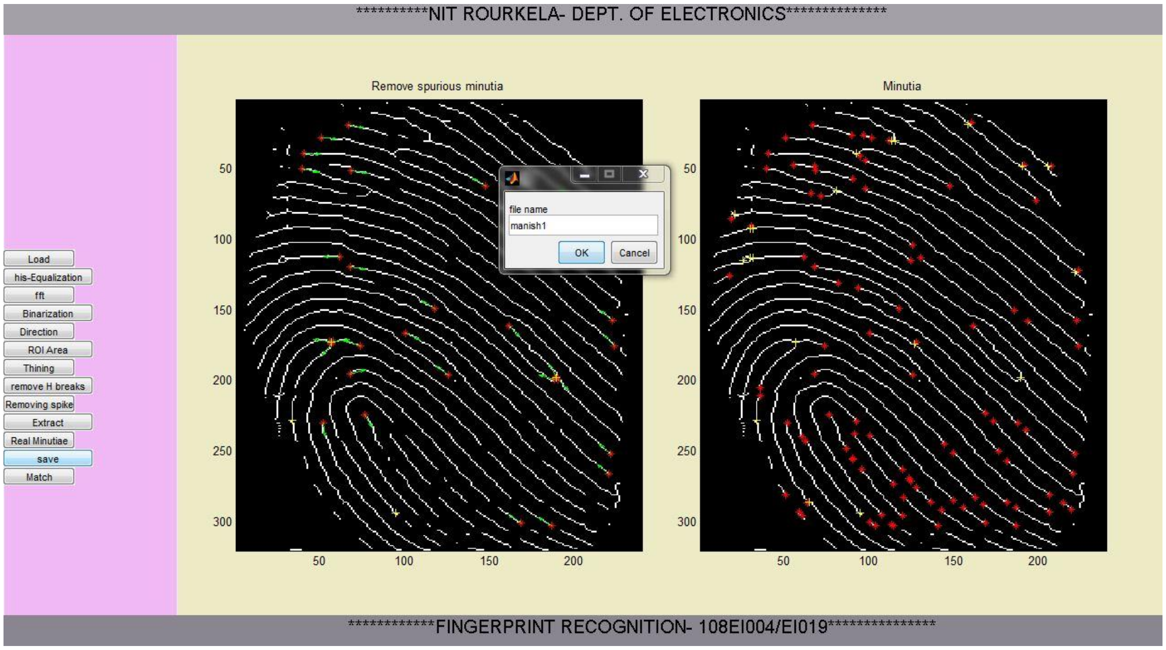

FIG: MINUTIAE DETAILS ARE SAVED

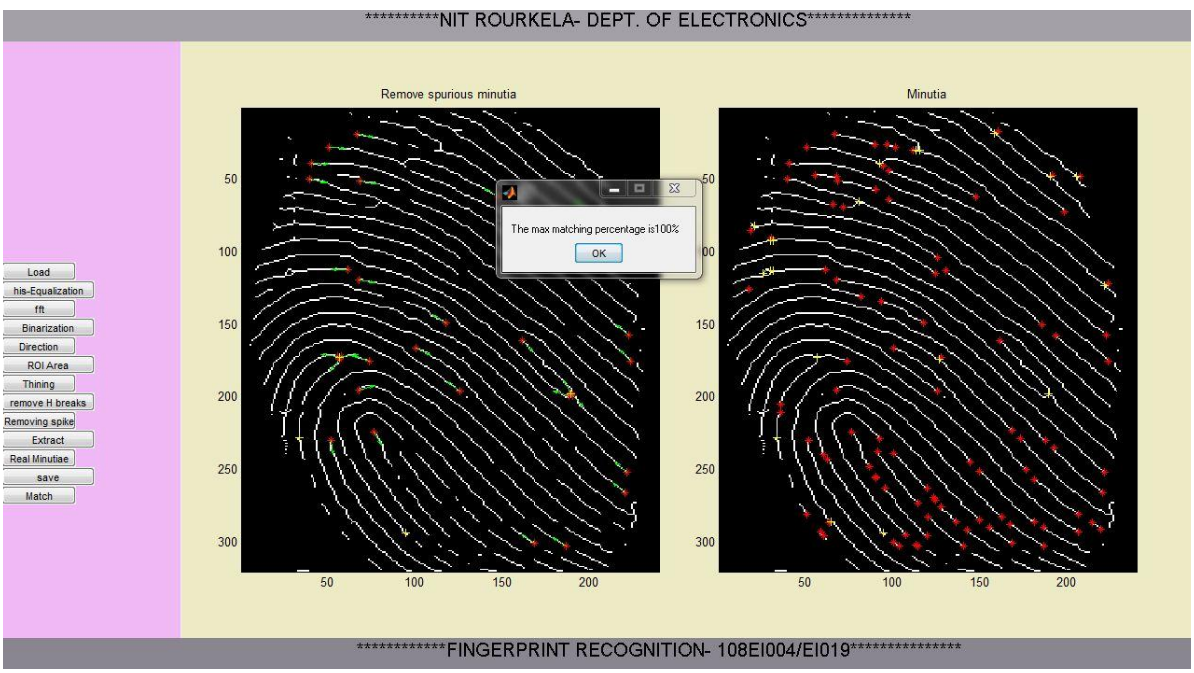

FIG: FINGERPRINT MATCHING USING THE ONLNE STORED DATABASE

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